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DESCRIPTION**METHOD OF BRAKING INDUCTION MOTOR AND
CONTROL APPARATUS****Technical Field**

[0001]

The present invention relates to an induction motor control device for stopping an induction motor, and more particularly, to a braking method and apparatus for controlling torque shock, caused by an abrupt change of an output current phase when a switch-over from a normal driving state to a direct current (DC) braking state is performed, to be reduced to a predetermined value or less by predictably operating an output voltage phase for flowing out a direction current.

Related Art

[0002]

On a conventional direct current (DC) braking function of an induction motor, a DC braking technique that is embedded in a high performance vector control device and not tripped (an abnormal stop of a control device) and a DC braking technique

having a small vibration during the induction motor is stopped are disclosed (for example, refer to a patent document 1). When the control device is tripped, the control device is abnormally stopped, and simultaneously, an alarm is displayed on a display part.

Fig. 14 is a block diagram illustrating a detailed example of a vector control device having a velocity sensor. The reference numeral 101 denotes a DC braking control arithmetic unit, which operates as shown in the flow chart of Fig. 15. The reference numeral 102 denotes a velocity control arithmetic unit, in which a torque current (corresponding to a torque) instruction iq^* is operated on the basis on a velocity instruction ω input from external systems of the vector control device and a velocity detection value ω_r (hereinafter, the reference symbol * denotes an instruction value). The reference numeral 103 denotes a magnetic flux arithmetic unit, where iq^* is input, a magnetic flux dividing current instruction id^* and a sliding frequency ws that satisfy a vector control condition are operated to output id^* , iq^* , and ws . The reference numeral 104 denotes a d-p axis ACR which operates voltage instructions vq^* and vd^* for

allowing current detection values i_q and i_d to follow i_{q*} and i_{d*} . The reference numeral 105 denotes an inverse d-q converter, which converts v_{q*} and v_{d*} from a rotation coordinate d-q axis into a three phase voltage instruction. The reference numeral 106 denotes a PWM arithmetic unit, which operates a firing pattern for turning on/off a switching element on the basis of a three phase voltage instruction. The reference numeral 107 denotes a power conversion circuit. The reference numeral 108 denotes a slip compensation arithmetic unit, which receives the output from the magnetic flux arithmetic unit 103 to operate a primary frequency ω_1 of the induction motor. The reference numeral 109 denotes an integrator, which integrates the primary frequency ω_1 and computes a phase θ_1 on a d-axis to output them to the d-q converter 111 or the inverse d-q converter 105. The reference numeral 110 denotes a velocity detection arithmetic unit, which operates the velocity based on the signal from the position detector such as an encoder or performs a velocity estimation based on a current or the like if the position detection does not exist. The reference numeral 111 denotes a d-q converter, which operates current detection values i_d and i_q

converted into rotation coordinates with respect to a phase θ_1 of a d-axis. The reference numeral 112 denotes a position detector such as an encoder, and the reference numeral 113 denotes an induction motor, which includes switches S101, S103, and S104 controlled by the DC braking control arithmetic unit 101. The DC braking control arithmetic unit 101 receives a braking force target value of the DC braking and a DC braking instruction (not shown in the drawing) used to switch over to the DC braking drive. When the vector control is performed, the switches S101, S103, and S104 are switched over to the side of "a" by the DC braking control arithmetic unit 1, and the vector control is performed as described above.

Referring to Fig. 15, in a step 201, the phase of a voltage vector θ_v is calculated only at an instant that a switch-over from the vector control to the DC braking is performed. In the step 202, the switch S101 is switched over to the side of "b" to input θ_v into θ_{dq} . In the step 203, the switch S103 is switched over to the side of "b" to input the instruction i_d^* of the ACR of the d-axis and the value corresponding to the braking force input to the DC braking control arithmetic unit 101 to the

ACR 104 of the d-q axis, so that the instruction iq^* of the ACR of the q-axis is set to 0. In a step 204, an absolute value of "iq" and a predetermined reference value " α " are compared. In the step 205a, if the absolute value "iq" is larger than the reference value " α ", the switch S104 is switched over to the side of "a", so that the output of the ACR 104 of the d-q axis is delivered to the PWM arithmetic unit 106. In a step 205b, if the absolute value of "iq" is smaller than the reference value " α ", the switch S104 is switched over to the side of "b", the output of the ACR of the d-axis is validated, the q-axis voltage instruction Vq^* is set to zero ($Vq^*=0$, i.e., the ACR of the q-axis is invalidated), and the voltage instruction is output to the PWM arithmetic unit 106. Through the steps 204 and 205, it is possible to prevent vibration generated when a rotor position determination of an alternating current (AC) motor is stopped.

As described above, in a conventional induction motor control apparatus and its control method, the phase of the vector θ_v is calculated only at an instant that a switch-over from the vector control to the DC braking is performed, " θ_v " is input to " θ_{dq} ", the instruction iq^* of the ACR of the q-axis

is set to 0, and a control is performed by the ACR 104 of the d-q axis. Then, if the absolute value $|i_q|$ is smaller than the predetermined reference value α , the ACR of the q-axis is invalidated.

Patent Document 1: WO 98/11663, Figs. 1 and 2

Problems to be solved by the Invention

[0003]

The conventional induction motor control device and its control method discloses a DC braking method in the control device of the induction motor, in which the current supplied from the power conversing device is divided by vector components to perform a control. In addition, as described in the patent document 1 that torque is not generated in a low velocity range in the case of a V/f control, the DC braking is initiated when the frequency is equal to or lower than the setup DC braking initiation frequency in the V/f control. However, when the method disclosed in the patent document 1 is executed, it is impossible to set a variation of the current phase to be equal to or lower than a predetermined value because the setup DC braking initiation frequency is different from the rotation information of the induction motor. In addition, in

both of the vector controls that a velocity sensor is installed and the velocity sensor is not installed, if the rotation number is equal to or lower than a predetermined value at the state that the phase of the current instruction is fixed, it is necessary to fix the voltage phase, and other complicated processes are also generated. Furthermore, when the ACR 104 of the d-q axis is used to perform the control during the DC braking, the voltage phase is changed because the voltage instruction V_d^* of the d-axis and the voltage instruction V_q^* of the q-axis vary, so that a DC voltage and a DC current cannot be output.

The present invention is contrived solve the aforementioned problems, and is to provide a control apparatus and a braking method, by which an abrupt change of the current phase is inhibited and the torque shock can be reduced to a predetermined value or less when a switch-over from the normal control state to a DC braking state is performed by predictably operating the output voltage phase during the DC braking on the basis of the output voltage phase in a normal control state.

Means for Solving the Problems

[0004]

In order to solve the aforementioned problems, the present invention provides the following methods and apparatuses.

[0005]

The invention disclosed in claim 1 is a direct current (DC) braking method for stopping an induction motor using a control device including: a power converter for driving the induction motor, a PWM arithmetic unit for determining a switching pattern of the power converter on the basis of a primary voltage instruction and an output phase obtained by adding a voltage phase and a magnetic flux phase, a voltage arithmetic unit, a torque current controller and an excitation current controller, wherein torque shock generated by an abrupt change of an output current phase is reduced to a predetermined value or less by predictably operating an output voltage phase during the DC braking on the basis of an output voltage phase of a normal control state, when a switch-over from the normal control state to a DC braking state is performed.

[0006]

In the invention disclosed in claim 2, the

output voltage phase during the DC braking is predictably operated on the basis of an output voltage phase of the normal control state and a phase advanced until the DC braking is initiated.

[0007]

In the invention disclosed in claim 3, the phase advanced until the DC braking is initiated is operated on the basis of a setup DC braking initiation frequency.

[0008]

In the invention disclosed in claim 4, the phase advanced until the DC braking is initiated is operated on the basis of a deceleration rate and a setup DC braking initiation frequency.

[0009]

In the invention disclosed in claim 5, the torque shock during a restart is reduced to a predetermined value or less by controlling the output voltage phase during the DC braking with respect to a coordinate axis for a normal control.

[0010]

The invention disclosed in claim 6 is a control device capable of a DC braking for stopping an induction motor, the control device including: a power converter for driving the induction motor; a

PWM arithmetic unit for determining a switching pattern of the power converter on the basis of a primary voltage instruction and an output phase obtained by adding a voltage phase and a magnetic flux phase; a voltage arithmetic unit; a torque current controller; and an excitation voltage controller, wherein torque shock generated by an abrupt change of an output current phase is reduced to a predetermined value or less by predictably operating an output voltage phase during the DC braking on the basis of an output voltage phase of a normal control state, when a switch-over from the normal control state to a DC braking state is performed.

[0011]

In the invention disclosed in claim 7, the output voltage phase during the DC braking is predictably operated on the basis of an output voltage phase of the normal control state and a phase advanced until the DC braking is initiated.

[0012]

In the invention disclosed in claim 8, the phase advanced until the DC braking is initiated is operated on the basis of a setup DC braking initiation frequency.

[0013]

In the invention disclosed in claim 9, the phase advanced until the DC braking is initiated is operated on the basis of a deceleration rate and a setup DC braking initiation frequency.

[0014]

In the invention disclosed in claim 10, the torque shock during a restart is reduced to a predetermined value or less by controlling the output voltage phase during the DC braking with respect to a coordinate axis for a normal control.

Advantage of the Invention

[0015]

According to the invention disclosed in claim 1, in a DC braking method for stopping the induction motor, torque shock generated by an abrupt change of an output current phase can be reduced to a predetermined value or less by predictably operating an output voltage phase during a DC braking on the basis of an output voltage phase of a normal control state when a switch-over from the normal control state to a DC braking state is performed.

According to the invention disclosed in claim 2, since the output voltage phase during the DC braking

can be operated on the basis of the output voltage phase of the normal control state the phase advanced until the DC braking is initiated, it is possible to reduce the torque shock generated by an abrupt change of the output current phase to a predetermined value or less.

According to the invention disclosed in claim 3, since the phase advanced until the DC braking is initiated can be calculated on the basis of a setup DC braking initiation frequency, it is possible to reduce the torque shock generated by an abrupt change of the output current phase to a predetermined value or less.

According to the invention disclosed in claim 4, since the phase advanced until the DC braking is initiated can be operated on the basis of the deceleration rate and the setup DC braking initiation frequency, it is possible to reduce the torque shock generated by an abrupt change of the output current phase to a predetermined value or less.

According to the invention disclosed in claim 5, it is possible to reduce a torque shock generated during a restart to a predetermined value or less by controlling the output voltage phase during the DC

braking, predicted by the method of predictably operating the output voltage phase during the DC braking, with respect to the coordinate axis of the normal control.

According to the invention disclosed in claim 6, in an apparatus for controlling the induction motor, the torque shock generated by an abrupt change of the output current phase can be reduced to a predetermined value or less by predictably operating the output voltage phase during a DC braking on the basis of the output voltage phase of the normal control state when a switch-over from the normal control state to a DC braking state is performed.

According to the invention disclosed in claim 7, since the output voltage phase during the DC braking can be operated on the basis of the output voltage phase of the normal control state the phase advanced until the DC braking is initiated, it is possible to provide a control device capable of reducing the torque shock generated by an abrupt change of the output current phase to a predetermined value or less.

According to the invention disclosed in claim 8, since the phase advanced until the DC braking is initiated can be calculated on the basis of a setup

DC braking initiation frequency, it is possible to provide a control device capable of reducing the torque shock generated by an abrupt change of the output current phase to a predetermined value or less.

According to the invention disclosed in claim 9, since the phase advanced until the DC braking is initiated can be operated on the basis of the deceleration rate and the setup DC braking initiation frequency, it is possible to provide a control device capable of reducing the torque shock generated by an abrupt change of the output current phase to a predetermined value or less.

According to the invention disclosed in claim 10, it is possible to provide a control device capable of reducing the torque shock generated during a restart to a predetermined value or less by controlling the output voltage phase during the DC braking, predicted by the method of predictably operating the output voltage phase during the DC braking, with respect to the coordinate axis of the normal control.

Brief Description of the Drawings

[0016]

[Fig. 1]

Fig. 1 is a flowchart illustrating a method of applying a control device of an induction motor according to the first embodiment of the present invention.

[Fig. 2]

Fig. 2 is a flowchart illustrating a processing sequence of a method according to the present invention.

[Fig. 3]

Fig. 3 is a flowchart illustrating a method of applying a control device of an induction motor according to the second embodiment of the present invention.

[Fig. 4]

Fig. 4 is a block diagram illustrating a control device of an induction motor for applying a method according to the third embodiment of the present invention.

[Fig. 5]

Fig. 5 is a block diagram illustrating a control device of an induction motor for applying a method according to the fourth embodiment of the present invention.

[Fig. 6]

Fig. 6 is a block diagram illustrating a control device of an induction motor for applying a method according to the fifth embodiment of the present invention.

[Fig. 7]

Fig. 7 is a block diagram illustrating a control device of an induction motor for applying a method according to the sixth embodiment of the present invention.

[Fig. 8]

Fig. 8 is a block diagram illustrating a control device of an induction motor for applying a method according to the seventh embodiment of the present invention.

[Fig. 9]

Fig. 9 is a block diagram illustrating a control device of an induction motor for applying a method according to the eighth embodiment of the present invention.

[Fig. 10]

Fig. 10 is a block diagram illustrating a control device of an induction motor for applying a method according to the ninth embodiment of the present invention.

[Fig. 11]

Fig. 11 is a block diagram illustrating a control device of an induction motor for applying a method according to the tenth embodiment of the present invention.

[Fig. 12]

Fig. 12 is a block diagram illustrating a control device of an induction motor for applying a method according to the eleventh embodiment of the present invention.

[Fig. 13]

Fig. 13 is a block diagram illustrating a control device of an induction motor for applying a method according to the twelfth embodiment of the present invention.

[Fig. 14]

Fig. 14 is a block diagram illustrating a construction of an induction motor control device for applying a conventional method.

[Fig. 15]

Fig. 15 is a flowchart illustrating a processing sequence of a conventional method.

Description of Reference Numerals and Signs

[0017]

1: POWER CONVERTER

2: AC MOTOR
3: CURRENT DETECTOR
4: d-q CONVERTER
5: TORQUE CURRENT CONTROLLER
6: EXCITATION CURRENT CONTROLLER
7: PHASE CONVERTER
8: INTEGRATOR
9: VOLTAGE ARITHMETIC UNIT
10: PWM ARITHMETIC UNIT
11: VOLTAGE PHASE PREDICTION ARITHMETIC UNIT
12: PHASE PREDICTOR
13: PRIMARY CURRENT CONTROLLER
101: DC BRAKING CONTROL ARITHMETIC UNIT
102: VELOCITY CONTROL ARITHMETIC UNIT
103: MAGNETIC FLUX ARITHMETIC UNIT
104: d and q AXES ACR
105: INVERSE d-q CONVERTER
106: PWM ARITHMETIC UNIT
107: POWER CONVERSION CIRCUIT
108: SLIDING COMPENSATION ARITHMETIC UNIT
109: INTEGRATOR
110: VELOCITY DETECTION ARITHMETIC UNIT
111: d-q CONVERSION UNIT
112: POSITION DETECTOR
113: INDUCTION MOTOR

114: BRAKING FORCE TARGET VALUE OF DC BRAKING
S1, S2, S3, S4, S101, S103 and S104: SWITCHES

Best Mode for Carrying Out the Invention

[0018]

Hereinafter, the embodiments of the present invention will be described in detail with reference to the accompanying drawings.

Embodiment 1

[0019]

Fig. 1 is a flowchart illustrating a control device of an induction motor for applying a method according the first embodiment of the invention, and Fig. 2 is a flowchart illustrating a processing sequence of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, a torque current controller 5, an excitation current controller 6, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, and switches S1, S2, and S3. The power converter 1 converts a three phase AC current into a DC voltage

having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the induction motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value i_q and an excitation current detection value i_d . The torque current controller 5 operates the q-axis voltage correction value V_{qc} such that the received torque current instruction value i_{q*} corresponds with the torque current detection value i_q . The excitation current controller 6 operates the d-axis voltage correction value V_{dc} so that the received excitation current instruction value i_{d*} corresponds with the excitation current detection value i_d . The phase converter 7 converts the received frequency f_1* into a phase amount $\Delta\theta_{dq}$ between the samplings. The integrator 8 integrates the value $\Delta\theta_{dq}$ output from the phase converter 7 to operate a magnetic flux phase θ_{dq} . The voltage arithmetic unit 9 operates a primary voltage instruction V_1* and a voltage phase θ using the following equation, on the basis of a d-axis voltage instruction V_d^* obtained by adding the received d-axis voltage instruction V_d^* and the d-

axis voltage correction value V_{dc} by setting a q-axis voltage instruction $V_{q''}$ to zero or a value obtained by adding the q-axis voltage correction value V_{qc} and the q-axis voltage instruction $V_{q''}$ given by the switch S1.

[0020]

[Equation 1]

$$V_{l^*} = \sqrt{V_{d^*}^2 + V_{q^*}^2} \quad (1)$$

$$\theta = \tan^{-1} \frac{V_{q^*}}{V_{d^*}} \quad (2)$$

[0021]

The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V_{l^*} and the output phase θ_v obtained by adding the voltage phase θ and the magnetic flux phase θ_{dq} . The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value $\Delta\theta_{dq}$ output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking

initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount $\Delta\theta_{dq}$ between the samplings.

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency f_1^* corresponds with the DC braking initiation frequency f_{db} during a deceleration. If the received frequency f_1^* is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency f_1^* corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S3 are operated in the side of "a" as the normal control state, and the FLG is set to zero (FLG=0), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, the q-axis voltage instruction Vq^* obtained by adding the received q-axis voltage instruction Vq^* and the q-axis voltage correction value Vqc , and the d-axis voltage instruction Vd^*

obtained by adding the received d-axis voltage instruction Vd^* and the d-axis voltage correction value Vdc are input to the voltage arithmetic unit 9. The phase amount $\Delta\theta_{dq}$ between the samplings is operated by the phase converter 7 on the basis of the received frequency $f1^*$, and the magnetic flux phase θ_{dq} is operated by the integrator 8. In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1 and S2 are switched over from the side of "a" to the side of "b". Accordingly, the q-axis voltage instruction Vq^* is set to zero ($Vq^*=0$), and the phase amount $\Delta\theta_{dq}$ between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed,

so that a value obtained by adding a voltage phase of the normal control state and the phase amount $\Delta\theta_{dq}$ obtained in the step 2a is substituted for the magnetic flux phase θ_{dq} to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θ_{dq} .

In the step of the PWM arithmetic unit, the primary voltage instruction $V1^*$ and the voltage phase θ are operated from the d-axis voltage instruction Vd^* and the q-axis voltage instruction Vq^* , and the output phase θ_v is operated from the voltage phase θ and the magnetic flux phase θ_{dq} , so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when

a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 2

[0022]

Fig. 3 is a block diagram illustrating a control device of an induction motor for applying a method according to the second embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, a torque current controller 5, an excitation current controller 6, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, and switches S2, S3, and S4. The power converter 1 converts a three phase AC current

into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the induction motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value i_q and an excitation current detection value i_d . The torque current controller 5 operates the q-axis voltage correction value V_{qc} such that the received torque current instruction value i_{q*} corresponds with the torque current detection value i_q . The excitation current controller 6 operates the d-axis voltage correction value V_{dc} such that the received excitation current instruction value i_{d*} corresponds with the excitation current detection value i_d . The phase converter 7 converts the received frequency f_1^* into a phase amount $\Delta\theta_{dq}$ between the samplings. The integrator 8 integrates the value $\Delta\theta_{dq}$ output from the phase converter 7 to operate the magnetic flux phase θ_{dq} . The voltage arithmetic unit 9 operates a primary voltage instruction V_1^* and a voltage phase θ , on the basis of a q-axis voltage instruction V_{q*}' obtained by adding the q-axis voltage correction value V_{qc} and the received q-axis

voltage instruction Vq^* by setting the d-axis voltage instruction $Vd^{*\prime}$ to zero or a value obtained by adding the d-axis voltage correction value Vdc and the d-axis voltage instruction Vd^* given by the switch S4. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction $V1^*$ and the output phase θ_v obtained by adding the voltage phase θ and the magnetic flux phase θ_{dq} . The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state is performed and the value $\Delta\theta_{dq}$ output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount $\Delta\theta_{dq}$ between the samplings.

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal

control state. In this step, it is determined whether or not the received frequency $f1^*$ corresponds with the DC braking initiation frequency f_{db} during a deceleration. If the received frequency $f1^*$ is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency $f1^*$ corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S2 to S4 are operated in the side of "a" as the normal control state, and the FLG is set to zero ($FLG=0$), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, the q-axis voltage instruction Vq^* obtained by adding the received q-axis voltage instruction Vq^* and the q-axis voltage correction value Vqc , and the d-axis voltage instruction Vd^* obtained by adding the received d-axis voltage instruction Vd^* and the d-axis voltage correction value Vdc are input to the voltage arithmetic unit 9. The phase amount $\Delta\theta_{dq}$ between the samplings is operated by the phase converter 7 on the basis of the received frequency $f1^*$, and the magnetic flux phase θ_{dq} is operated by the integrator 8. In the step 2b, as a process of switching over from the

normal control state to the DC braking state, the switches S2 and S4 re switched over from the side of "a" to the side of "b". Accordingly, the q-axis voltage instruction Vq^* is set to zero ($Vq^*=0$), and the phase amount $\Delta\theta_{dq}$ between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed, and the voltage phase θ_v of the normal control state is rotated by 90° . However, its rotation direction is determined by the sign of the received frequency $f1^*$. A value obtained by adding this phase angle and the phase amount $\Delta\theta_{dq}$ obtained in the step 2a is substituted for the magnetic flux phase θ_{dq} to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set

to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θ_{dq} .

In the step of the PWM arithmetic unit, the primary voltage instruction V_1^* and the voltage phase θ are operated from the d-axis voltage instruction V_d^* and the q-axis voltage instruction V_q^* , and the output phase θ_v is operated from the voltage phase θ and the magnetic flux phase θ_{dq} , so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current

phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 3

[0023]

Fig. 4 is a block diagram illustrating a control device of an induction motor for applying a method according to the third embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, a torque current controller 5, an excitation current controller 6, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, a primary current controller 13, and switches S1, S2, S3, and S4. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the induction motor 2. The d-q converter 4 separates

the current detected by the current detector 3 into a torque current detection value i_q and an excitation current detection value i_d . In addition, the primary current detection value i_1 is output. The torque current controller 5 operates the q-axis voltage correction value V_{qc} so that a received torque current instruction value i_q^* corresponds with the torque current detection value i_q . The excitation current controller 6 operates the d-axis voltage correction value V_{dc} so that the received excitation current instruction value i_d^* corresponds with the excitation current detection value i_d . The phase converter 7 converts the received frequency f_1^* into a phase amount $\Delta\theta_{dq}$ between the samplings. The integrator 8 integrates the value $\Delta\theta_{dq}$ output from the phase converter 7 to operate the magnetic flux phase θ_{dq} . The voltage arithmetic unit 9 operates a primary voltage instruction V_1^* and a voltage phase θ , by setting a q-axis voltage instruction V_q^* to zero or a value obtained by adding the received q-axis voltage instruction V_q^* and the q-axis voltage correction value V_{qc} and by setting a d-axis voltage instruction V_d^* to the primary voltage correction value V_{lc} or a value obtained by adding the d-axis voltage correction

value V_{dc} and the d-axis voltage instruction V_{d^*} given by the switch S4. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V_{1^*} and the output phase θ_v obtained by adding the voltage phase θ and the magnetic flux phase θ_{dq} . The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value $\Delta\theta_{dq}$ output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount $\Delta\theta_{dq}$ between the samplings. The primary current controller 13 outputs a primary voltage correction value V_{1c} so that the received primary current instruction i_{1^*} corresponds with the primary current detection value i_1 .

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a

step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency $f1^*$ corresponds with the DC braking initiation frequency f_{db} during a deceleration. If the received frequency $f1^*$ is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency $f1^*$ corresponds with the DC braking initiation frequency, a process advances to a step 2b.

In a step 2a, the switches S1 to S4 are operated in the side of "a" as the normal control state, and the FLG is set to zero ($FLG=0$), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, a q-axis voltage instruction Vq^* obtained by adding the received q-axis voltage instruction Vq^* and the q-axis voltage correction value Vqc , and a d-axis voltage instruction Vd^* obtained by adding the received d-axis voltage instruction Vd^* and the d-axis voltage correction value Vdc are input to the voltage arithmetic unit 9. The phase amount $\Delta\theta_{dq}$ between the samplings is operated by the phase converter 7 on the basis of the received frequency $f1^*$, and the magnetic flux phase θ_{dq} is operated by

the integrator 8. In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1, S2, and S4 are switched over from the side of "a" to the side of "b". Accordingly, the q-axis voltage instruction Vq^* is set to zero ($Vq^*=0$), the d-axis voltage instruction Vd^* is output such that the primary current instruction $i1^*$ given for the DC braking corresponds with the primary current detection value $i1$, and the phase amount $\Delta\theta_{dq}$ between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed, and a value obtained by adding the voltage phase θ_v of the normal control state and the phase amount $\Delta\theta_{dq}$ operated in the step 2a is substituted for the

magnetic flux phase θ_{dq} to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θ_{dq} .

In the step of the PWM arithmetic unit, the primary voltage instruction V_1^* and the voltage phase θ are operated from the d-axis voltage instruction V_d^* and the q-axis voltage instruction V_q^* , and the output phase θ_v is operated from the voltage phase θ and the magnetic flux phase θ_{dq} , so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC

braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 4

[0024]

Fig. 5 is a block diagram illustrating a control device of an induction motor for applying a method according to the fourth embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, a torque current controller 5, an excitation current controller 6, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, a primary current controller 13, and switches S1, S2, S3, and S4. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method

and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the induction motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value i_q and an excitation current detection value i_d . In addition, the primary current detection value i_1 is output. The torque current controller 5 operates the q-axis voltage correction value V_{qc} so that a received torque current instruction value i_q^* corresponds with the torque current detection value i_q . The excitation current controller 6 operates the d-axis voltage correction value V_{dc} so that the received excitation current instruction value i_d^* corresponds with the excitation current detection value i_d . The phase converter 7 converts the received frequency f_1^* into a phase amount $\Delta\theta_{dq}$ between the samplings. The integrator 8 integrates the value $\Delta\theta_{dq}$ output from the phase converter 7 to operate the magnetic flux phase θ_{dq} . The voltage arithmetic unit 9 operates a primary voltage instruction V_1^* and a voltage phase θ , by setting the q-axis voltage instruction V_q^* to the primary voltage correction value V_{1c} or a value obtained by adding the q-axis voltage instruction V_q^* given by the switch S1 and

the q-axis voltage correction value V_{qc} and by setting a d-axis voltage instruction V_{d^*}' to zero or a value obtained by adding the d-axis voltage instruction V_{d^*} given by the switch S4 and the d-axis voltage correction value V_{dc} . The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V_{1^*} and the output phase θ_v obtained by adding the voltage phase θ and the magnetic flux phase θ_{dq} . The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value $\Delta\theta_{dq}$ output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount $\Delta\theta_{dq}$ between the samplings. The primary current controller 13 outputs a primary voltage correction value V_{1c} so that the received primary current instruction i_{1^*} corresponds with the primary current detection value i_1 .

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency $f1^*$ corresponds with the DC braking initiation frequency f_{db} during a deceleration. If the received frequency $f1^*$ is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency $f1^*$ corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S4 are operated in the side of "a" as the normal control state, and the FLG is set to zero ($FLG=0$), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, a q-axis voltage instruction Vq^* obtained by adding the received q-axis voltage instruction Vq^* and the q-axis voltage correction value Vqc , and a d-axis voltage instruction Vd^* obtained by adding the received d-axis voltage instruction Vd^* and the d-axis voltage correction value Vdc are input to the voltage arithmetic unit 9. The phase amount $\Delta\theta_{dq}$ between the samplings is

operated by the phase converter 7 on the basis of the received frequency f_1^* , and the magnetic flux phase θ_{dq} is operated by the integrator 8. In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1, S2, and S4 are switched over from the side of "a" to the side of "b". Accordingly, the q-axis voltage instruction V_{q^*}' is set to zero ($V_{q^*}'=0$), the d-axis voltage instruction V_{d^*}' is output such that the primary current instruction i_1^* given for the DC braking corresponds with the primary current detection value i_1 , and the phase amount $\Delta\theta_{dq}$ between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed,

and the voltage phase θ_v of the normal control state is rotated by 90° . However, its rotation direction is determined by the sign of the received frequency f_1^* . A value obtained by adding this phase angle and the phase amount $\Delta\theta_{dq}$ operated in the step 2a is substituted for the magnetic flux phase θ_{dq} so as to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θ_{dq} .

In the step of the PWM arithmetic unit, the primary voltage instruction V_1^* and the voltage phase θ are operated from the d-axis voltage instruction V_d^* and the q-axis voltage instruction V_q^* , and the output phase θ_v is operated from the voltage phase θ and the magnetic flux phase θ_{dq} , so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the

induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 5

[0025]

Fig. 6 is a block diagram illustrating a control device of an induction motor for applying a method according to the fifth embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, an excitation current controller 6, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, and

switches S1, S2, S3, and S4. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the induction motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value i_q and an excitation current detection value i_d . The excitation current controller 6 operates the d-axis voltage correction value V_{dc} so that the received excitation current instruction value i_d^* corresponds with the excitation current detection value i_d . The phase converter 7 converts the received frequency f_1^* into a phase amount $\Delta\theta_{dq}$ between the samplings. The integrator 8 integrates the value $\Delta\theta_{dq}$ output from the phase converter 7 to operate the magnetic flux phase θ_{dq} . The voltage arithmetic unit 9 operates a primary voltage instruction V_1^* and a voltage phase θ , by inputting zero or the q-axis voltage instruction V_q^* given by the switch S1 as a q-axis voltage instruction $V_q^{*''}$ and by inputting zero or the d-axis voltage correction value V_{dc} as a d-axis voltage instruction $V_d^{*''}$ by the switch S4. The PWM

arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction $V1^*$ and the output phase θ_v obtained by adding the voltage phase θ and the magnetic flux phase θ_{dq} . The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value $\Delta\theta_{dq}$ output from the phase predictor. The phase detector 12 predictably calculates the velocity of the AC motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount $\Delta\theta_{dq}$ between the samplings.

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency $f1^*$ corresponds with the DC braking initiation frequency f_{db} during a deceleration. If the received frequency $f1^*$ is higher than the DC braking initiation

frequency, a process advances to a step 2a as the normal control state. If the received frequency $f1^*$ corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S4 are operated in the side of "a" as the normal control state, and the FLG is set to zero ($FLG=0$), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, the q-axis voltage instruction $Vq^{*''}$ is set to the received q-axis voltage instruction Vq^* , and the d-axis voltage instruction $Vd^{*''}$ is set to zero ($Vd^{*''}=0$), so that they are input to the voltage arithmetic unit 9. Accordingly, the phase amount $\Delta\theta_{dq}$ between the samplings is operated by the phase converter 7 based on the received frequency $f1^*$, and the integrator 8 operates the magnetic flux phase θ_{dq} . In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1, S2, and S4 are switched over from the side of "a" to the side of "b". Accordingly, the q-axis voltage instruction $Vq^{*''}$ is set to zero ($Vq^{*''}=0$), the d-axis voltage instruction $Vd^{*''}$ is output such that the excitation current instruction id^* given for the DC braking corresponds with the excitation current detection value id , and the phase

amount $\Delta\theta_{dq}$ between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed, and a value obtained by the voltage phase θ_v of the normal control state and the phase amount $\Delta\theta_{dq}$ obtained in the step 2a is substituted for the magnetic flux phase θ_{dq} , so as to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θ_{dq} .

In the step of the PWM arithmetic unit, the primary voltage instruction $V1^*$ and the voltage phase θ are operated from the d-axis voltage instruction Vd^* and the q-axis voltage instruction Vq^* , and the output phase θ_v is operated from the voltage phase θ and the magnetic flux phase θ_{dq} , so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the AC motor 2 by predicting the velocity of the AC motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 6

[0026]

Fig. 7 is a block diagram illustrating a

control device of an induction motor for applying a method according to the sixth embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an AC motor 2, a current detector 3, a d-q converter 4, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, a primary current controller 13, and switches S1, S2, S3, and S4. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the AC motor 2. The current detector 3 detects the current supplied to the AC motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value i_q and an excitation current detection value i_d . In addition, a primary current detection value i_1 is output. The phase converter 7 converts the received frequency f_1^* into a phase amount $\Delta\theta_{dq}$ between the samplings. The integrator 8 integrates the value $\Delta\theta_{dq}$ output from the phase converter 7 to operate the magnetic flux phase θ_{dq} . The voltage

arithmetic unit 9 operates a primary voltage instruction $V1^*$ and a voltage phase θ , by inputting zero or the q-axis voltage instruction Vq^* given by the switch S1 as a q-axis voltage instruction Vq^* ' and by inputting zero or the primary voltage correction value $V1c$ as the d-axis voltage instruction Vd^* ' by the switch S4. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction $V1^*$ and the output phase θ_v obtained by adding the voltage phase θ and the magnetic flux phase θ_{dq} .

The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value $\Delta\theta_{dq}$ output from the phase predictor. The phase detector 12 predictably calculates the velocity of the AC motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount $\Delta\theta_{dq}$ between the samplings. The primary current controller 13 outputs the primary

voltage correction value V_{1c} such that the received primary current instruction i_1^* corresponds with the primary current detection value i_1 .

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency f_1^* corresponds with the DC braking initiation frequency f_{db} during a deceleration. If the received frequency f_1^* is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency f_1^* corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S4 are operated in the side of "a" as the normal control state, and the FLG is set to zero ($FLG=0$), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, the q-axis voltage instruction V_{q^*}' is set to the received q-axis voltage instruction V_{q^*} , and the d-axis voltage instruction V_{d^*}' is set to zero ($V_{d^*}'=0$), so that they are input to the voltage arithmetic unit 9. Accordingly, the phase amount

$\Delta\theta_{dq}$ between the samplings is operated by the phase converter 7 based on the received frequency f_1^* , and the integrator 8 operates the magnetic flux phase θ_{dq} . In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1, S2, and S4 are switched over from the side of "a" to the side of "b". Accordingly, the q-axis voltage instruction V_{q^*}' is set to zero ($V_{q^*}'=0$), the d-axis voltage instruction V_{d^*}' is set to the primary voltage correction value V_{1c} operated such that the primary current instruction i_1^* given for a DC braking corresponds with the primary current detection value i_1 , and the phase amount $\Delta\theta_{dq}$ between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the AC motor 2. Then, a process advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC

braking state is performed, and a value obtained by the voltage phase θ_v of the normal control state and the phase amount $\Delta\theta_{dq}$ obtained in the step 2a is substituted for the magnetic flux phase θ_{dq} , so as to match the phases between the normal control state and the DC braking initiation.

In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θ_{dq} .

In the step of the PWM arithmetic unit, the primary voltage instruction V_1^* and the voltage phase θ are operated from the d-axis voltage instruction V_d^* and the q-axis voltage instruction V_q^* , and the output phase θ_v is operated from the voltage phase θ and the magnetic flux phase θ_{dq} , so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the AC motor 2 by predicting the velocity of the AC motor 2 using the phase predictor 12 when a switch-over from

the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 7

[0027]

Fig. 8 is a block diagram illustrating a control device of an induction motor for applying a method according to the seventh embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, an excitation current controller 6, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, and switches S1, S2, S3, and S4. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a

power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the induction motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value i_q and an excitation current detection value i_d . The excitation current controller 6 operates the d-axis voltage correction value V_{dc} so that the received excitation current instruction value i_d^* corresponds with the excitation current detection value i_d . The phase converter 7 converts the received frequency f_1^* into a phase amount $\Delta\theta_{dq}$ between the samplings. The integrator 8 integrates the value $\Delta\theta_{dq}$ output from the phase converter 7 to operate the magnetic flux phase θ_{dq} . The voltage arithmetic unit 9 operates a primary voltage instruction V_1^* and a voltage phase θ , by setting a q-axis voltage instruction V_q^* to zero or the q-axis voltage instruction V_q^* given by the switch S1 and by setting a d-axis voltage instruction V_d^* to zero or the d-axis voltage correction value V_{dc} by the switch S4. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V_1^* and the output phase θ_v obtained by

adding the voltage phase θ and the magnetic flux phase θ_{dq} . The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value $\Delta\theta_{dq}$ output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount $\Delta\theta_{dq}$ between the samplings.

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency f_1^* corresponds with the DC braking initiation frequency f_{db} during a deceleration. If the received frequency f_1^* is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency f_1^*

corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S4 are operated in the side of "a" as the normal control state, and the FLG is set to zero (FLG=0), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, a q-axis voltage instruction Vq^* is set to the received q-axis voltage instruction Vq^* , and the d-axis voltage instruction Vd^* is set to zero ($Vd^{*\prime}=0$), so that they are input to the voltage arithmetic unit 9. Accordingly, the phase amount $\Delta\theta_{dq}$ between the samplings is operated by the phase converter 7 based on the received frequency $f1^*$, and the integrator 8 operates the magnetic flux phase θ_{dq} . In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1, S2, and S4 are switched over from the side of "a" to the side of "b". Accordingly, the q-axis voltage instruction Vq^* is set to zero ($Vq^{*\prime}=0$), the d-axis voltage instruction Vd^* is output such that the received current instruction id^* given for the DC control corresponds with the d-axis current detection value id , and the phase amount $\Delta\theta_{dq}$ between the samplings is predictably calculated by the phase detector 12 on the basis of

the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed, and the phase θ_{dq} of the magnetic flux of the normal control state is rotated by 90° . However, its rotation direction is determined by the sign of the received frequency f_1^* . A value obtained by adding this phase angle and the phase amount $\Delta\theta_{dq}$ operated in the step 2a is substituted for the magnetic flux phase θ_{dq} , so as to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θ_{dq} .

In the step of the PWM arithmetic unit, the primary voltage instruction $V1^*$ and the voltage phase θ are operated from the d-axis voltage instruction Vd^* and the q-axis voltage instruction Vq^* , and the output phase θ_v is operated from the voltage phase θ and the magnetic flux phase θ_{dq} , so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 8

[0028]

Fig. 9 is a block diagram illustrating a control device of an induction motor for applying a method according to the eighth embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, a primary current controller 13, and switches S1, S2, S3, and S4. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the AC motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value i_q and an excitation current detection value i_d . In addition, a primary current detection value i_1 is output. The phase converter 7 converts the received frequency f_1^* into a phase amount $\Delta\theta_{dq}$ between the samplings. The integrator 8 integrates the value $\Delta\theta_{dq}$ output from the phase

converter 7 to operate the magnetic flux phase θ_{dq} . The voltage arithmetic unit 9 operates a primary voltage instruction $V1^*$ and a voltage phase θ , by setting a q-axis voltage instruction Vq^* to zero or the q-axis voltage instruction Vq^* given by the switch S1 and by setting a d-axis voltage instruction Vd^* to zero or the primary voltage correction value $V1c$ by the switch S4. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction $V1^*$ and the output phase θ_v obtained by adding the voltage phase θ and the magnetic flux phase θ_{dq} . The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value $\Delta\theta_{dq}$ output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount $\Delta\theta_{dq}$ between the samplings. The primary current controller 13 outputs

the primary voltage correction value V_{1c} such that the received primary current instruction i_1^* corresponds with the primary current detection value i_1 .

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency f_1^* corresponds with the DC braking initiation frequency f_{db} during a deceleration. If the received frequency f_1^* is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency f_1^* corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S4 are operated in the side of "a" as the normal control state, and the FLG is set to zero ($FLG=0$), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, the q-axis voltage instruction V_{q^*}' is set to the received q-axis voltage instruction V_{q^*} , and the d-axis voltage instruction V_{d^*}' is set to zero ($V_{d^*}'=0$), so that they are input to the voltage

arithmetic unit 9. Accordingly, the phase amount $\Delta\theta_{dq}$ between the samplings is operated by the phase converter 7 based on the received frequency f_1^* , and the integrator 8 operates the magnetic flux phase θ_{dq} . In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1, S2, and S4 are switched over from the side of "a" to the side of "b". Accordingly, the q-axis voltage instruction V_{q^*}' is set to zero ($V_{q^*}'=0$), the primary voltage correction value V_{1c} is operated such that the primary current instruction i_1^* given for a DC control corresponds with the primary current detection value i_1 is output as the d-axis voltage instruction V_{d^*}' , and the phase amount $\Delta\theta_{dq}$ between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to

the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed, and the magnetic flux phase θ_{dq} of the normal control state is rotated by 90° . However, its rotation direction is determined by the sign of the received frequency f_1^* . A value obtained by adding this phase angle and the phase amount $\Delta\theta_{dq}$ operated in the step 2a is substituted for the magnetic flux phase θ_{dq} , so as to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θ_{dq} .

In the step of the PWM arithmetic unit, the primary voltage instruction V_1^* and the voltage phase θ are operated from the d-axis voltage instruction V_d^* and the q-axis voltage instruction V_q^* , and the output phase θ_v is operated from the voltage phase θ and the magnetic flux phase θ_{dq} , so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase

prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 9

[0029]

Fig. 10 is a block diagram illustrating a control device of an induction motor for applying a method according to the ninth embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, a torque current controller 5, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM

arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, and switches S1, S2, and S3. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the induction motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value i_q and an excitation current detection value i_d . In addition, a primary current detection value i_l is output. The torque current controller 5 operates the q-axis voltage correction value V_{qc} such that the received excitation current instruction value i_d^* corresponds with the torque current detection value i_q . The phase converter 7 converts the received frequency f_1^* into a phase amount $\Delta\theta_{dq}$ between the samplings. The integrator 8 integrates the value $\Delta\theta_{dq}$ output from the phase converter 7 to operate the magnetic flux phase θ_{dq} . The voltage arithmetic unit 9 operates a primary voltage instruction V_1^* and a voltage phase θ , by setting a q-axis voltage instruction V_q^* to a q-axis voltage correction

value V_{qc} or the q-axis voltage instruction Vq^* given by the switch S1 and by setting a d-axis voltage instruction Vd^* to zero. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction $V1^*$ and the output phase θ_v obtained by adding the voltage phase θ and the magnetic flux phase θ_{dq} . The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value $\Delta\theta_{dq}$ output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount $\Delta\theta_{dq}$ between the samplings.

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency $f1^*$

corresponds with the DC braking initiation frequency f_{db} during a deceleration. If the received frequency f_1^* is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency f_1^* corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S3 are operated in the side of "a" as the normal control state, and the FLG is set to zero ($FLG=0$), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, a q-axis voltage instruction Vq^* is set to the received q-axis voltage instruction Vq^* , and the d-axis voltage instruction Vd^* is set to zero ($Vd^{**}=0$), so that they are input to the voltage arithmetic unit 9. Accordingly, the phase amount $\Delta\theta_{dq}$ between the samplings is operated by the phase converter 7 based on the received frequency f_1^* , and the integrator 8 operates the magnetic flux phase θ_{dq} . In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1 and S2 are switched over from the side of "a" to the side of "b". Accordingly, the d-axis voltage instruction Vd^* is set to zero ($Vd^{**}=0$), the q-axis voltage correction value Vqc

operated such that the received current instruction i_{q^*} given for the DC control corresponds with the q-axis current detection value i_q is output as the q-axis voltage instruction V_{q^*} , and the phase amount $\Delta\theta_{dq}$ between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed, and the voltage phase θ_v of the normal control state is rotated by 90° . However, its rotation direction is determined by the sign of the received frequency f_1^* . A value obtained by adding this phase angle and the phase amount $\Delta\theta_{dq}$ operated in the step 2a is substituted for the magnetic flux phase θ_{dq} , so as to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set to one

(FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θ_{dq} . In the step of the PWM arithmetic unit, the primary voltage instruction V_1^* and the voltage phase θ are operated from the d-axis voltage instruction V_d^* and the q-axis voltage instruction V_q^* , and the output phase θ_v is operated from the voltage phase θ and the magnetic flux phase θ_{dq} , so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an

electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 10

[0030]

Fig. 11 is a block diagram illustrating a control device of an induction motor for applying a method according to the tenth embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, a primary current controller 13, and switches S1, S2, and S3. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the AC motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value i_q and an excitation current detection value

id. In addition, a primary current detection value i_1 is output. The phase converter 7 converts the received frequency f_1^* into a phase amount $\Delta\theta_{dq}$ between the samplings. The integrator 8 integrates the value $\Delta\theta_{dq}$ output from the phase converter 7 to operate the magnetic flux phase θ_{dq} . The voltage arithmetic unit 9 operates a primary voltage instruction V_1^* and a voltage phase θ , by setting a q-axis voltage instruction V_q^* to the q-axis voltage instruction V_q^* given by the switch S1 or the primary voltage correction value V_{1c} and by setting a d-axis voltage instruction V_d^* to zero. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V_1^* and the output phase θ_v obtained by adding the voltage phase θ and the magnetic flux phase θ_{dq} . The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value $\Delta\theta_{dq}$ output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking

initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount $\Delta\theta_{dq}$ between the samplings. The primary current controller 13 outputs the primary voltage correction value V_{1c} such that the received primary current instruction i_1^* corresponds with the primary current detection value i_1 .

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency f_1^* corresponds with the DC braking initiation frequency f_{db} during a deceleration. If the received frequency f_1^* is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency f_1^* corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S3 are operated in the side of "a" as the normal control state, and the FLG is set to zero (FLG=0), so that a process advances to a step of the PWM arithmetic unit which will be described below.

In this case, the q-axis voltage instruction Vq^* is set to the received q-axis voltage instruction Vq^* , and the d-axis voltage instruction Vd^* is set to zero ($Vd^*=0$), so that they are input to the voltage arithmetic unit 9. Accordingly, the phase amount $\Delta\theta_{dq}$ between the samplings is operated by the phase converter 7 based on the received frequency $f1^*$, and the integrator 8 operates the magnetic flux phase θ_{dq} . In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1 and S2, are switched over from the side of "a" to the side of "b". Accordingly, the d-axis voltage instruction Vd^* is set to zero ($Vd^*=0$), the primary voltage correction value $V1c$ operated such that the primary current instruction $i1^*$ given for a DC control corresponds with the primary current detection value $i1$ is output as the q-axis voltage instruction Vq^* , and the phase amount $\Delta\theta_{dq}$ between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process advances to a step 3, in which it is determined

whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed, and the voltage phase θ_v of the normal control state is rotated by 90° . However, its rotation direction is determined by the sign of the received frequency f_1^* . A value obtained by adding this phase angle and the phase amount $\Delta\theta_{dq}$ operated in the step 2a is substituted for the magnetic flux phase θ_{dq} , so as to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θ_{dq} . In the step of the PWM arithmetic unit, the primary voltage instruction V_1^* and the voltage phase θ are operated from the d-axis voltage instruction V_d^* and the q-axis voltage instruction V_q^* , and the output phase θ_v is operated from the voltage phase θ and the magnetic flux phase θ_{dq} , so

that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 11

[0031]

Fig. 12 is a block diagram illustrating a control device of an induction motor for applying a method according to the eleventh embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2,

a current detector 3, a d-q converter 4, a torque current controller 5, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, and switches S1, S2, and S3. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the induction motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value i_q and an excitation current detection value i_d . In addition, a primary current detection value i_1 is output. The torque current controller 5 operates the q-axis voltage correction value V_{qc} such that the received excitation current instruction value i_d^* corresponds with the torque current detection value i_q . The phase converter 7 converts the received frequency f_1^* into a phase amount $\Delta\theta_{dq}$ between the samplings. The integrator 8 integrates the value $\Delta\theta_{dq}$ output from the phase converter 7 to operate the magnetic flux phase θ_{dq} . The voltage arithmetic unit 9

operates a primary voltage instruction V_1^* and a voltage phase θ , by setting a q-axis voltage instruction V_q^* to a q-axis voltage correction value V_{qc} or the q-axis voltage instruction V_q^* given by the switch S1 and by setting a d-axis voltage instruction V_d^* to zero. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V_1^* and the output phase θ_v obtained by adding the voltage phase θ and the magnetic flux phase θ_{dq} . The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value $\Delta\theta_{dq}$ output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount $\Delta\theta_{dq}$ between the samplings.

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a

step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency $f1^*$ corresponds with the DC braking initiation frequency f_{db} during a deceleration. If the received frequency $f1^*$ is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency $f1^*$ corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S3 are operated in the side of "a" as the normal control state, and the FLG is set to zero ($FLG=0$), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, a q-axis voltage instruction Vq^* is set to the received q-axis voltage instruction Vq^* , and the d-axis voltage instruction Vd^* is set to zero ($Vd^*=0$), so that they are input to the voltage arithmetic unit 9. Accordingly, the phase amount $\Delta\theta_{dq}$ between the samplings is operated by the phase converter 7 based on the received frequency $f1^*$, and the integrator 8 operates the magnetic flux phase θ_{dq} . In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1 and S2 are switched over from

the side of "a" to the side of "b". Accordingly, the d-axis voltage instruction Vd^* is set to zero ($Vd^*=0$), the q-axis voltage correction value Vqc operated such that the received current instruction iq^* given for the DC control corresponds with the q-axis current detection value iq is output as the q-axis voltage instruction Vq^* , and the phase amount $\Delta\theta_{dq}$ between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed, and a value obtained by adding the magnetic flux phase θ_{dq} of the normal control state and the phase amount $\Delta\theta_{dq}$ operated in the step 2a is substituted for the magnetic flux phase θ_{dq} , so as to match the phases between the normal control state and the DC braking initiation.

In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θ_{dq} .

In the step of the PWM arithmetic unit, the primary voltage instruction V_1^* and the voltage phase θ are operated from the d-axis voltage instruction V_d^* and the q-axis voltage instruction V_q^* , and the output phase θ_v is operated from the voltage phase θ and the magnetic flux phase θ_{dq} , so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current

phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 12

[0032]

Fig. 13 is a block diagram illustrating a control device of an induction motor for applying a method according to the twelfth embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, a primary current controller 13, and switches S1, S2, and S3. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the AC motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection

value i_q and an excitation current detection value i_d . In addition, a primary current detection value i_l is output. The phase converter 7 converts the received frequency f_1^* into a phase amount $\Delta\theta_{dq}$ between the samplings. The integrator 8 integrates the value $\Delta\theta_{dq}$ output from the phase converter 7 to operate the magnetic flux phase θ_{dq} . The voltage arithmetic unit 9 operates a primary voltage instruction V_1^* and a voltage phase θ , by setting a q-axis voltage instruction V_q^* to the q-axis voltage instruction V_q^* given by the switch S1 or the primary voltage correction value V_{1c} and by setting a d-axis voltage instruction V_d^* to zero. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V_1^* and the output phase θ_v obtained by adding the voltage phase θ and the magnetic flux phase θ_{dq} . The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value $\Delta\theta_{dq}$ output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the

DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount $\Delta\theta_{dq}$ between the samplings. The primary current controller 13 outputs the primary voltage correction value V_{1c} such that the received primary current instruction i_{1*} corresponds with the primary current detection value i_1 .

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency f_{1*} corresponds with the DC braking initiation frequency f_{db} during a deceleration. If the received frequency f_{1*} is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency f_{1*} corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S3 are operated in the side of "a" as the normal control state, and the FLG is set to zero (FLG=0), so that a process advances to a step of the

PWM arithmetic unit which will be described below. In this case, the q-axis voltage instruction $Vq^{* \prime}$ is set to the received q-axis voltage instruction Vq^* , and the d-axis voltage instruction $Vd^{* \prime}$ is set to zero ($Vd^{* \prime} = 0$), so that they are input to the voltage arithmetic unit 9. Accordingly, the phase amount $\Delta\theta_{dq}$ between the samplings is operated by the phase converter 7 based on the received frequency $f1^*$, and the integrator 8 operates the magnetic flux phase θ_{dq} . In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1 and S2 are switched over from the side of "a" to the side of "b". Accordingly, the d-axis voltage instruction $Vd^{* \prime}$ is set to zero ($Vd^{* \prime} = 0$), the primary voltage correction value $V1c$ is operated such that the primary current instruction $i1^*$ given for a DC control corresponds with the primary current detection value $i1$ is output as the q-axis voltage instruction $Vq^{* \prime}$, and the phase amount $\Delta\theta_{dq}$ between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process

advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed, and a value obtained by adding the voltage phase θ_v of the normal control state and the phase amount $\Delta\theta_{dq}$ operated in the step 2a is substituted for the magnetic flux phase θ_{dq} , so as to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θ_{dq} .

In the step of the PWM arithmetic unit, the primary voltage instruction V_1^* and the voltage phase θ are operated from the d-axis voltage instruction V_d^* and the q-axis voltage instruction V_q^* , and the output phase θ_v is operated from the voltage phase θ and the magnetic flux phase θ_{dq} , so

that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

The present invention may be employed not only in an induction motor control device that uses, so called, a sensor less vector control method but also in a vector control device having a sensor or a control device that uses a V/f control method.

Industrial Applicability

[0033]

According to the present invention, it is possible to reduce the torque shock generated by an abrupt change of the output current phase to a predetermined value or less by predictably operating an output voltage phase during a DC braking on the basis of an output voltage phase of a normal control state when a switch-over from the normal control state to the DC braking state is performed. Therefore, the present invention may be employed in a usage for preventing an induction motor from being not rotated until the brake is closed, such as an application for determining a position or an elevating machinery(for example, an elevator, a crane, and a hoist).